U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

SOLAR ENERGY TECHNOLOGIES OFFICE

2020 SETO PEER REVIEW

CSP Systems: Gen 3 CSP

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Solar Energy Technologies Office

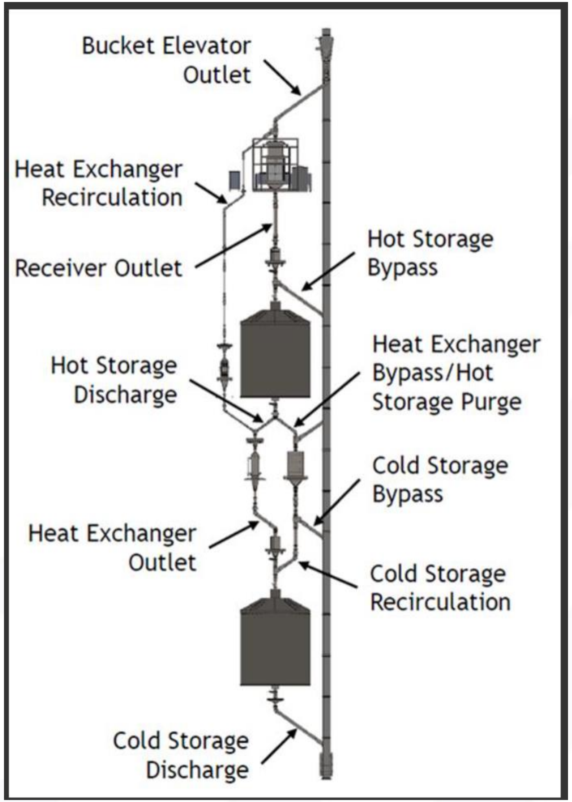
energy.gov/solar-office

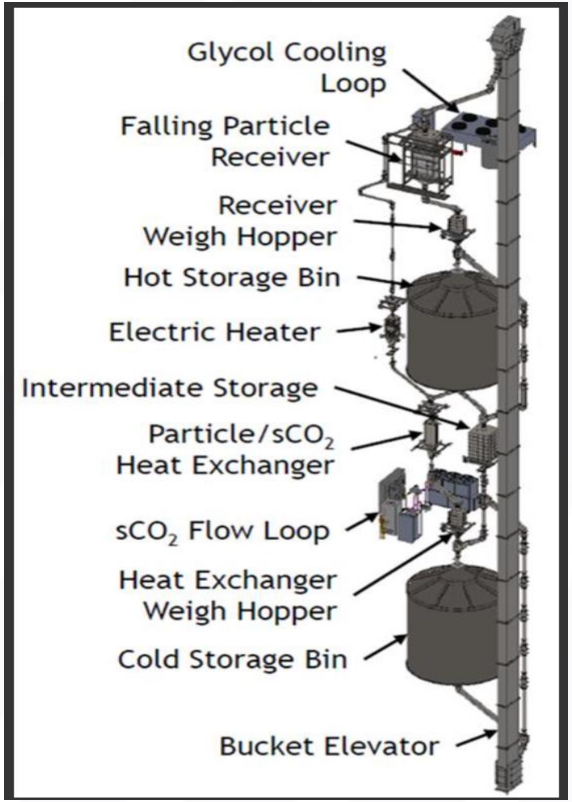
CSP Systems: Gen 3 Particle Pathway

Sandia National Laboratories

Challenges

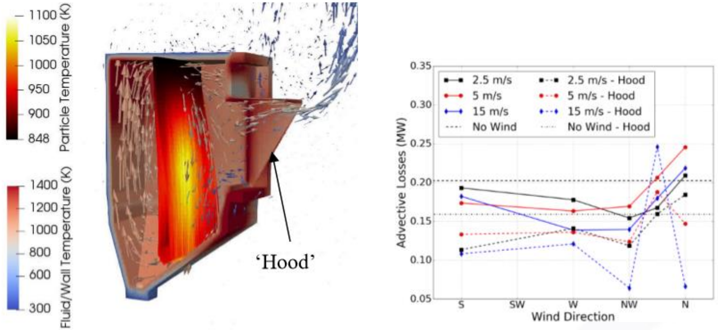
- Receiver thermal efficiency
- Particle-to-sCO2 HXer design
- Mass flow control





Gen 3 Particle Pathway R&D Efforts

Receiver Efficiency and Losses



Particle – sCO2 Heat Exchanger

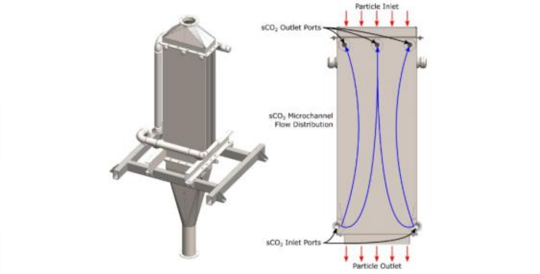


Figure 12. Illustration of the 1 MW_t G3P3 shell-and-plate moving packed-bed heat exchanger (left) and cut plane indicating the particle flow channel and integral sCO_2 ports (right)

Receiver Design and Modelling

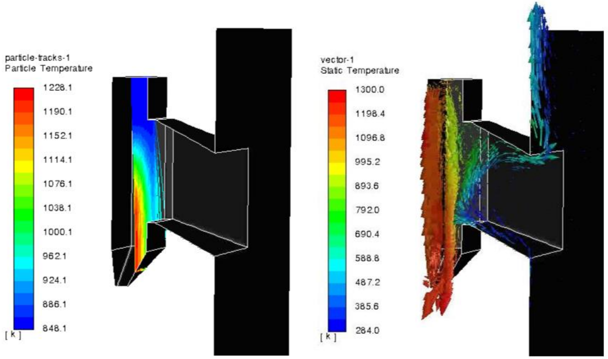


Figure 5. Steady-state particle temperatures (left) and air velocity vectors along the plane of symmetry colored by temperature in K (right) [20].

Thermal Energy Storage (Particle Silo)

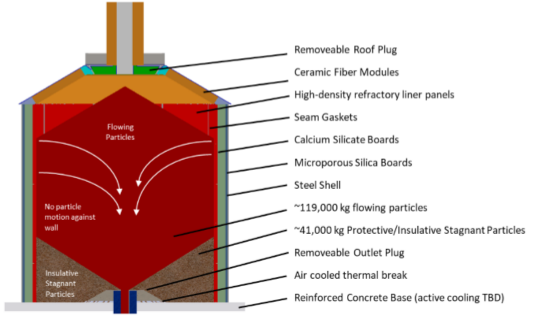


Figure 8. G3P3 Thermal Energy Storage Bin design overview

Gen 3 Particle Pathway R&D : Facilities

NSTTF Facility

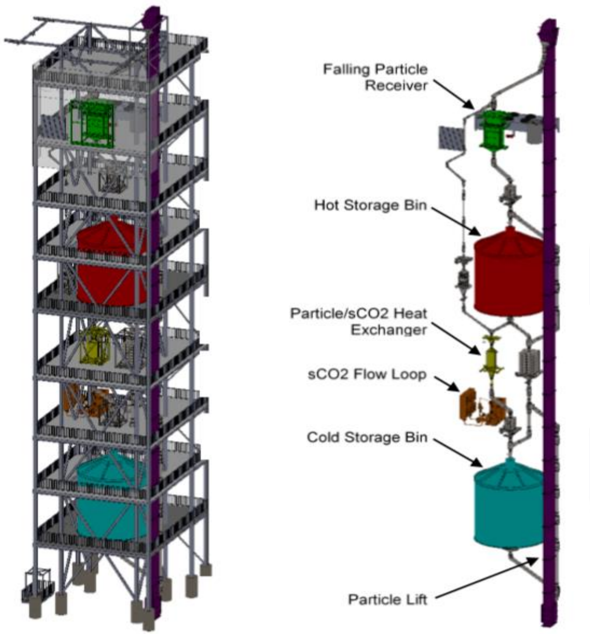


Figure 19. Illustration of vertically integrated G3P3 system showing supporting tower structure (left) and with the tower structure omitted (right) to display the particle connections

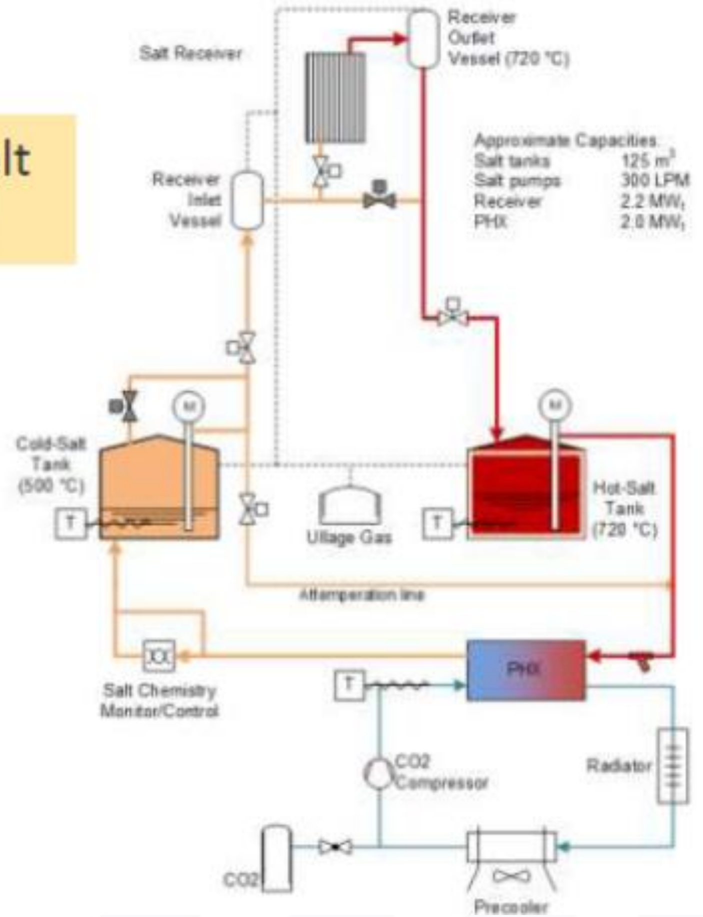
King Saud University Facility

Figure 132. Photograph of the particle-heating receiver test facility at King Saud University.

CSP Systems: Gen3 Liquid Pathway R&D

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Cl-Salt HTF



Challenges

- Material compatibility
- Corrosion mitigation
- Chemical monitoring and control

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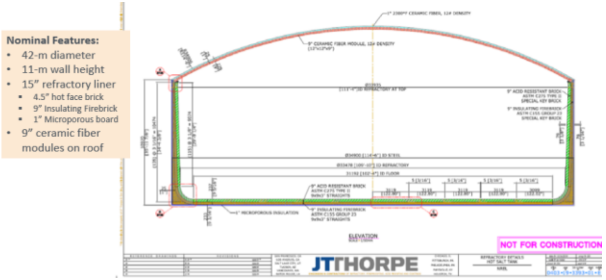
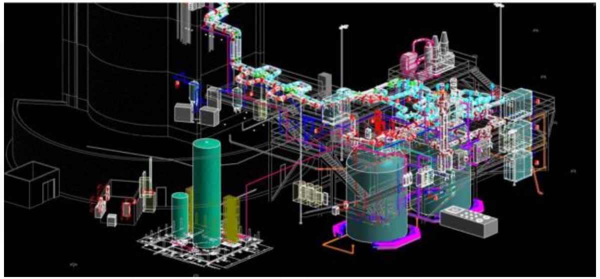
Gen 3 Liquid Pathway R&D Efforts

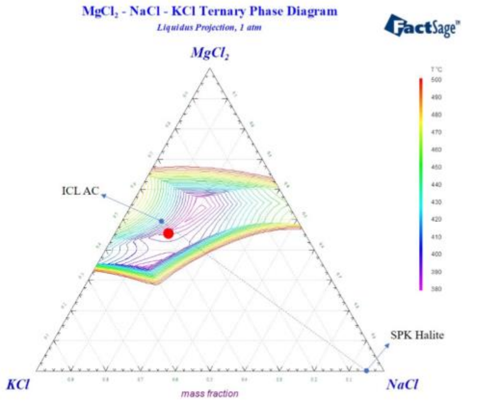
Salt Tank Design



System Integration



Salt Corrosion Mitigation and Control



Other Key Systems and Components

- Salt-sCO2 Heat Exchanger
- Piping and Valves
- Ullage Gas System
- Salt Melter
- Freeze Protection
- Scrubber / Vapor Removal

Liquid Pathway R&D Efforts: Sodium Receiver

Benefits of Sodium

- large heat transfer coefficient (α) , efficiently transfers thermal energy to HTF resulting in a high performance receiver
- greater flexibility in receiver and field design
- stability at high T_{op} – Na stable up to its boiling point (880°C)
- lower LCOE (Na: $71.4/MWh, salt: $79.5/MWh

Flexibility of Sodium

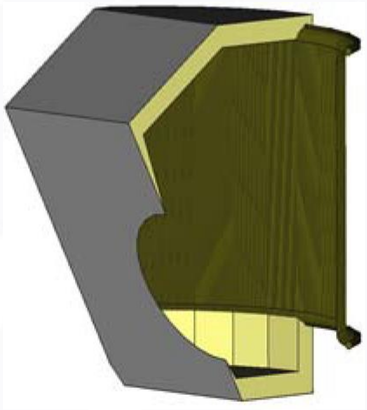
- With Na, the solar sub-system retains flexibility
- Na allows for a modular plant design enabling Na flow in networks, access to lower cost towers and the switch to more efficient optics
- higher fluxes and better heat transfer attributes enable alternative, advanced receiver design options

Receiver Down Select

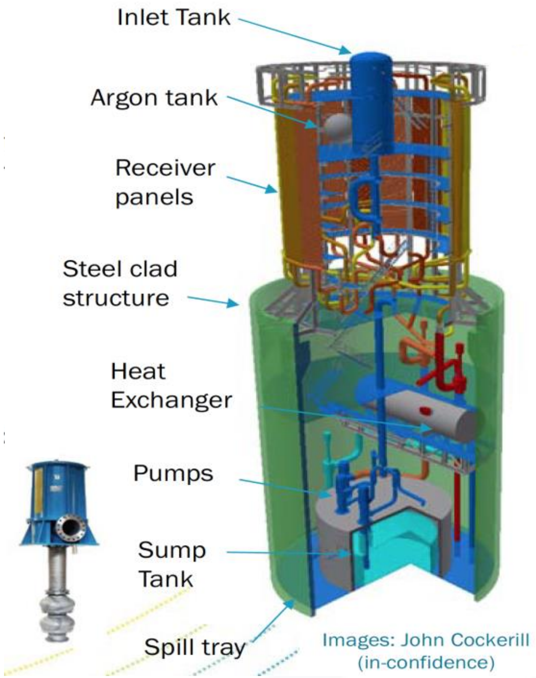
- two full scale $500MW_{th}$ Na receivers developed by ASTRI
- cylindrical receiver applicable to central and tower systems
- cavity receiver applicable to tower systems
- cylindrical receiver chosen as ***costs are understood with higher certainty***, ***operation is simpler*** and ***design is low risk***

Cavity Receiver Design Assumptions

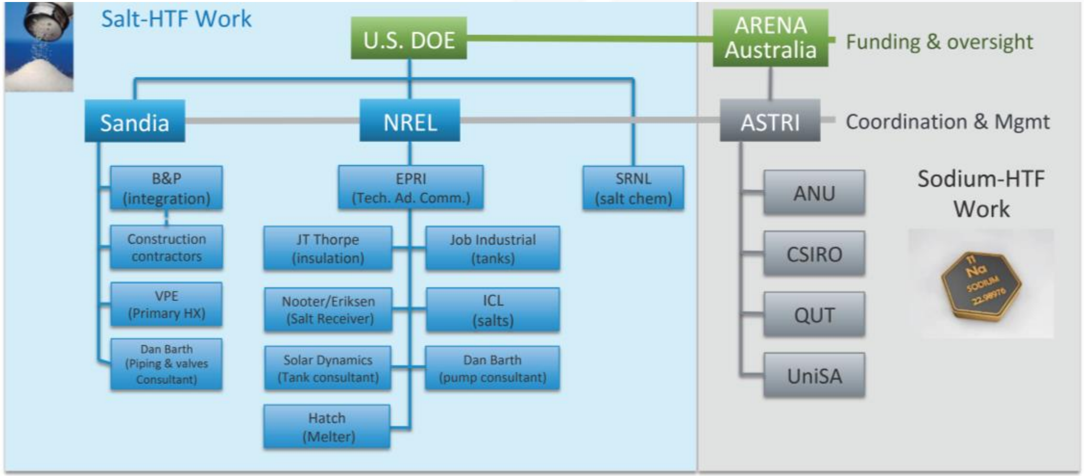
- 30-yr lifetime modeled for minimum creep-fatigue aggression
- flux limits evaluated for temperature and mass flow
- high-performance coating (90% absorptivity, 91% emissivity)

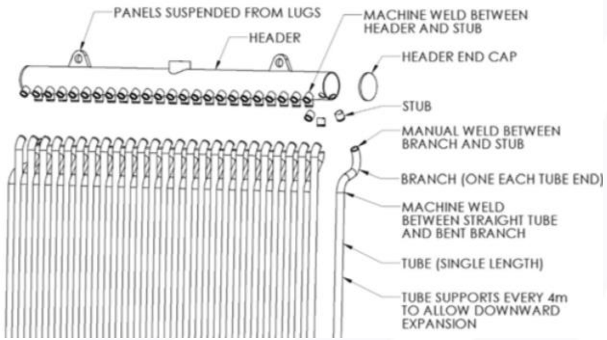


Liquid Pathway R&D: Sodium Receiver Integration



Images: John Cockerill (in-confidence)





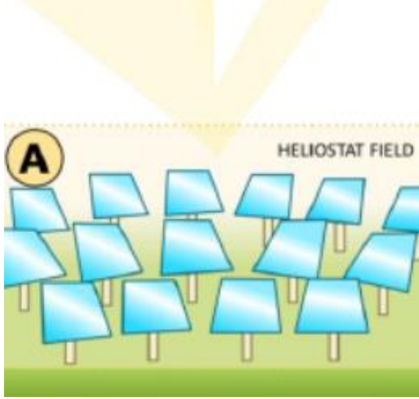
NREL

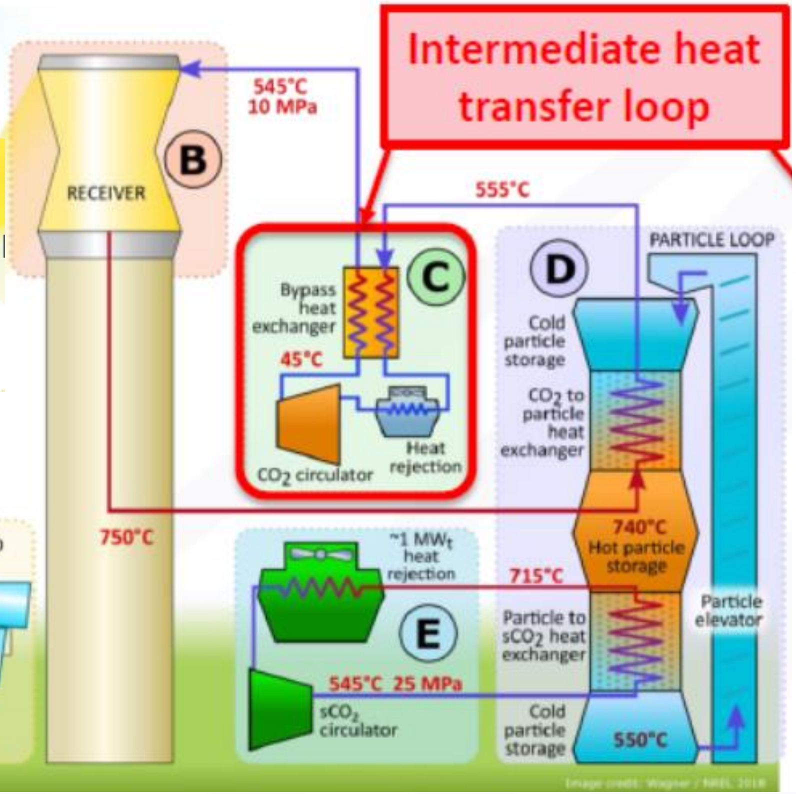
- project lead managing the technical output, subcontractor duties and budgetary needs throughout all phases of the project effort
- oversee the pilot operation
- stability at high T_{op} – Na stable up to its boiling point (880°C)

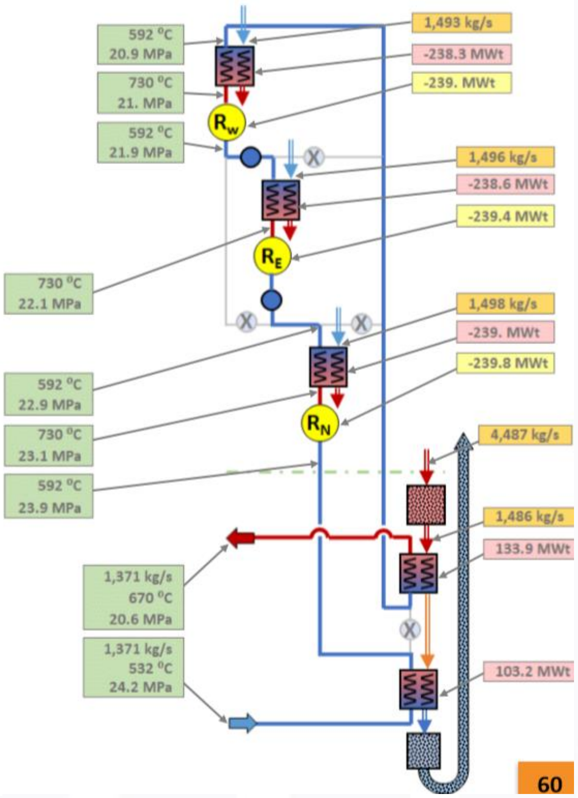
CSP Systems: Gen3 Gas Pathway

Challenges

- Overall system efficiency
- Design of indirect thermal energy storage
- Capital cost of heat exchange surface area

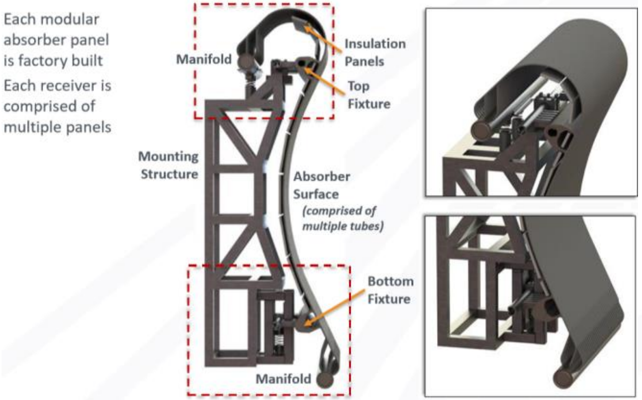


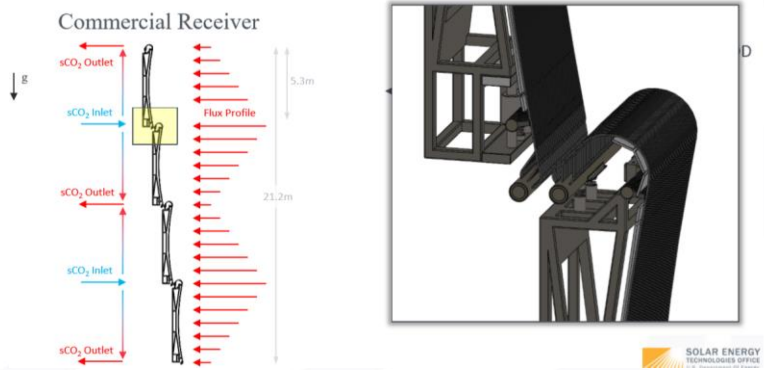




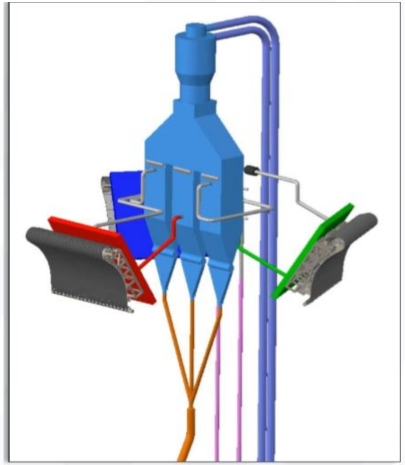
Gen 3 Gas Pathway R&D Efforts

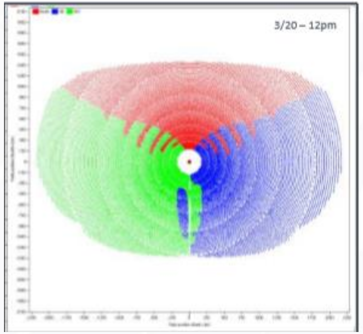
Receiver Design



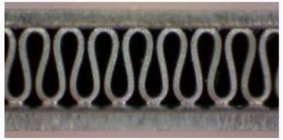


Tower and Solar Field Design





Internally Finned Structure

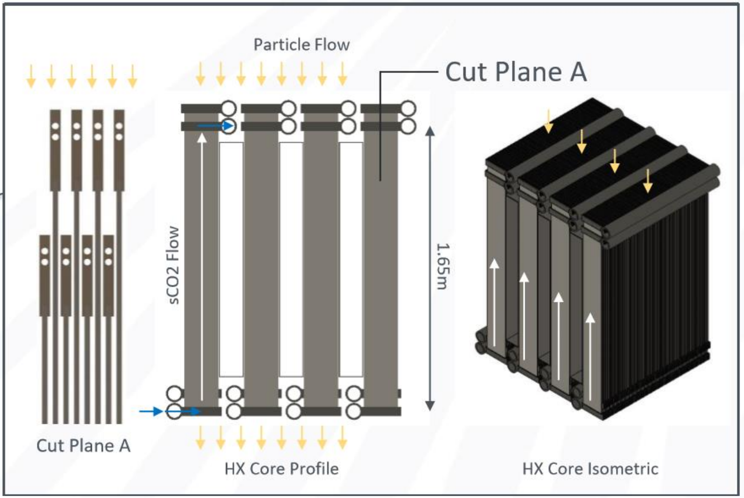


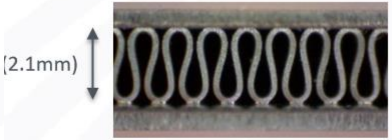
Edisun Heliostats

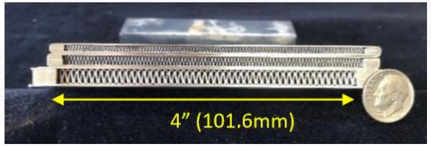
Edisun Heliostat

Gen 3 Gas Pathway R&D Efforts

Heat Exchanger







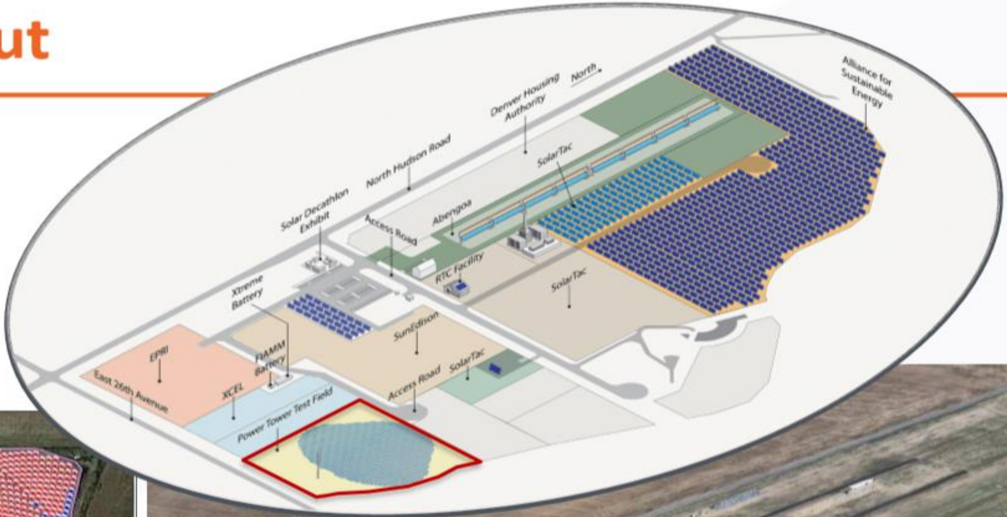
Particle Thermal Energy Storage (Sand)

MATERIAL	COMPOSITION	MATERIAL PROPERTIES			PRICE RANGE ($/Ton)
		DENSITY (kg/m3)	SPECIFIC HEAT (J/kg°C)	MELTING T (°C)	
Silica sand	SiO_2	2,610	1,000	1,710	30 – 80
Alumina	Brown fused Al_2O_3 (BFA)	3,960	1,200	1,500	100 – 1,000
Coal ash	SiO_2, Al_2O_3, + minerals	2,100	720 at 25°C	1,183–1,640	-40 – 20
Calcined flint clay	SiO_2, Al_2O_3, TiO_2, Fe_2O_3	2,600	1,050	2,000	350 – 400
CARBO proppants	75% Al_2O_3, 11% SiO_2, 9% Fe_2O_3, 3% TiO_2	3,300	1,150		1,000 – 2,000

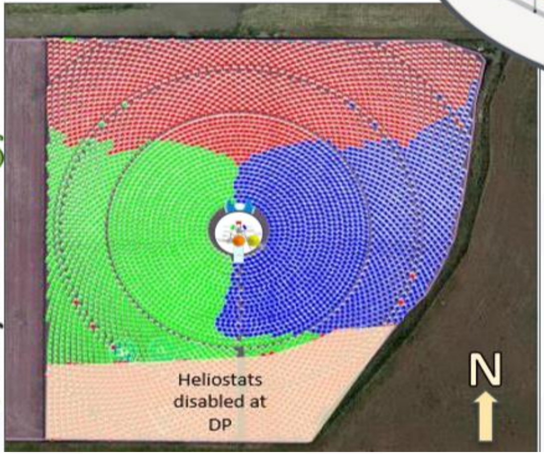
Gen3 Gas Pathway – Site Layout (Phase 3)

Phase 3 Layout

- Surround field
- Downward-tilted receivers to accommodate compressed field



- Proximal to microgrid
- Close to NREL, Airport



Gen3 Program

- Gen3 FOA Schedule

- Phase 1 (Research)	- FY 2019
- Phase 2 (Engineering)	- FY 2020
- Downselection Start Date	- Oct 1, 2020
- Phase 3 (Construction/Testing)	- FY 2021 - 2023

- Technical Advisory Committee (TAC)
- Industry Review

Downselect Criteria

- Technology Risk
- Project Management
- Technoeconomic Analysis (LCOE)
- Phase 3 De-Risking Activities
- Scale Up Risk

QUESTIONS?